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Formaldehyde and Other Disinfectants in the Control of Lettuce Diseases

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Formaldehyde and Other Disinfectants in the Control of Lettuce Diseases

W. S. Beach*

Introduction

MOST OF THE LETTUCE CROP in Pennsylvania is grown during spring or fall, in the open, frequently with the use of Skinner irrigation. A small but relatively more profitable part is grown in coldframes, in which case seed is sowed during the autumn and maturity is reached in early spring after an interval of arrested growth in winter. There is also a very profitable acreage resulting from transplanting into the open in early spring, the seedlings being started in coldframes during the autumn or winter. In the northern part of the state, mature lettuce as well as seedlings are grown in greenhouses.

The fungi seriously attacking lettuce in Pennsylvania are *Sclerotinia sclerotiorum* (Lib.) *Massee* (*S. libertiana* Fckl.), *Botrytis sp.*, *Rhizoctonia solani* Khun, and *Sclerotinia minor* Jagger, mentioned in order of their importance.

Nature of Losses

The extent and the nature of the losses caused by the respective fungi in cold frames and in the transplanted crop are shown in Tables I and II. In a period of seven years, *Sclerotinia sclerotiorum* caused an average annual loss of approximately sixteen per cent to lettuce maturing in the coldframes. In the transplanted lettuce, this fungus produces comparatively small loss. Although the parasite may cause the damping-off of certain areas in the seed beds, only in a small percentage of cases is it transferred upon seedlings to the field, apparently because workmen can avoid most affected plants. Extensive field infection is also rare in the transplanted crop since it matures before the germination of sclerotia and the dispersal of many ascospores in the open.

Botrytis caused severe disease in coldframes during two years of the seven when losses of nearly 40 per cent were sustained (Plate III, Fig. 7). Botrytis is predominantly associated with a more or less regular and important loss sustained by the transplanted lettuce. This loss varies from 5 to 50 per cent and occurs gradually between transplanting and maturity. The frequency of Botrytis indicates appar-

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PLATE I.

Fig. 1.—Loss of 35 per cent Caused by Sclerotinia sclerotiorum in Coldframe Lettuce. Many of the Diseased Plants Have Been Rogued.

Fig. 2.—Coldframe Lettuce Grown after Treatment of the Seedbed with Formaldehyde Showing the Well-formed Heads and an Excellent Stand.

ently that it is the chief cause of the loss, yet Rhizoctonia and, no doubt, certain other damping-off fungi are greater factors than field observations indicate, as it is difficult in taking field data to determine the loss for which they are primary causes. The low degree of parasitism of Botrytis, as well as the concurrent association of Rhizoctonia, leads to the view that the former occurs often as secondary infection.

During the greater part of the seed bed period in coldframes, the vigorous development of *Rhizoctonia solani* is prevented by temperatures that are much below its high optimum of 86-88 deg. F. (12). With the more favorable temperatures of fall or spring, the fungus causes damping-off, or, what is more usual, produces small lesions on the roots and the stems that lead to the death of the plants after transplanting.

Sclerotinia minor is not an important parasite in cold frame lettuce, although there is increasing evidence that it may become such.

In the spring sown crop in the field, loss by *S. sclerotiorum, S. minor* and *Botrytis sp.* seldom exceeds 10 per cent since rising temperatures and drying soils render conditions increasingly unfavorable for these fungi. In the fall, loss is slight or severe, depending on whether rainfall is light or heavy during the later stages of growth. Infections in excess of 60 per cent have been observed.

Rhizoctonia solani is an important parasite upon the spring crop of lettuce maturing in June or later months. At this time, the disease assumes the character of "black-bottom" (5) on certain damp soils. With rainy weather or an overamount of irrigation, almost entire fields may be ruined. The rosette type of the disease is frequently observed, but usually during spring or fall.

Previous Experimental Work Upon Control

Experiments to control lettuce-drop were first undertaken in the greenhouses of Massachusetts (24), and soil sterilization by steam was found to be effective. This was accomplished usually by laying perforated pipes in the bench soil and turning in steam until the soil was heated to a temperature of 180 deg.or higher for one-half to three-quarters of an hour. The higher the steam pressure used, the more effective and satisfactory the results. The treatment was recommended for the control of *Sclerotinia sclerotiorum* (*S. libertiana*), *Rhizoctonia solani, Pythium debaryanum* causing damping-off, and nematodes causing root-knot, but not for Botrytis or top burn.

In North Carolina, where lettuce is grown under canvas, early experimental work (18, 19) indicated that rogueing diseased plants as soon as they appear and drenching the loci of disease with Bordeaux mixture or bluestone solution would eliminate *S. sclerotiorum* (*S. libertiana*). *Subsequently, investigations were extended in that state, and it is stated that it was not so easy to control the disease, that old frames, old cloths, and refuse heaps were the sources of infection, very probably, where the diseased plants were eliminated as soon as they appeared.

*Letter to the author from Dr. F. A. Wolf, July 5, 1918.

Stevens (19) reported negative results with formaldehyde, but his dilution of the solution is now known to be too weak to kill the sclerotia of *S. sclerotiorum* in the soil. Reddick (15) also reported negative results with formaldehyde, while Clinton (4) first reported favorable results with this disinfectant.

In 1922, Poole (13) in a report from New Jersey showed successful control of *Sclerotinia sclerotiorum* (*S. libertiana*) with formaldehyde where the fungus attacked celery seedlings grown on muck soil in greenhouses. Three pints of the commercial formaldehyde added to 50 gallons of water were used to treat 50 square feet.

In 1923, Krout (9) in a report from Massachusetts showed that formaldehyde, 1-100 strength applied at the rate of a gallon to the square foot of soil surface, reduced lettuce-drop to a minimum of 2 to 4 percent in the greenhouse, and that the treatment was successful on a commercial scale. He showed further that this strength of the disinfectant would kill sclerotia at a depth of 20 inches provided they were in a moist condition, but those in an air-dry condition were not killed beyond eight inches.

In a previous paper, the author (1) reported moderate increases in the stand of lettuce where formaldehyde was applied to seedbeds in open fields, while the general results of the present work upon disinfection of coldframe soil with formaldehyde were published in an abstract (2). Lansing (10), reporting some data of the present work, has given certain of the more favorable results of the lettuce-drop control in coldframes by formaldehyde.

Peltier (12) reported poor results in his efforts to control *Rhizoctonia solani* on carnations by formaldehyde treatment of the soil. By steam sterilization, however, he obtained satisfactory control.

Johnson (7), in some fundamental studies on soil sterilization, stated that a strength of 1-50 is necessary for the complete control of Rhizoctonia and Pythium with formaldehyde. He used this strength of the disinfectant at the rate of two quarts to the square foot on small flats with soil of three inches depth.

It may be added that 1-50 strength of formaldehyde is used by certain greenhouses in Pennsylvania, but more than two quarts of solution to the square foot is required for most greenhouse benches and is essential in coldframes or the field.

There is extensive literature (3,8, 11, 16, 24, 25) relating to other benefits to crops from soil sterilization in addition to the destruction of plant parasites. These benefits are better quality and increased yield which is best measured by the weight of the product. Investigators disagree (8) as to how these benefits are obtained; their value, however, is a consideration in any outlay made for disease control by soil disinfection.

Experimental Objects

Although much has been published pertaining to the occurrence, the habits, and the control of *Sclerotinia*, *Botrytis* and *Rhizoctonia* on lettuce or other vegetables, it is noteworthy that entirely practical and efficient means of combating them are limited largely to special cultural conditions, particularly to greenhouses where sterilization is most applicable or where the objects of sanitation are most effectively

attained. For culture in the field or in coldframes, control measures effective elsewhere are not meeting the situation satisfactorily, or data regarding their effectiveness are lacking. Although the work of Krout (9) indicated great efficiency for formaldehyde on the heavily manured, highly organic, porous soils in Massachusetts greenhouses, it seemed possible that results might be different at Bustleton, Pennsylvania, on a loam with clay enough to retard greatly the percolation of water. Moreover, there existed a considerable number of other disinfectants whose effectiveness for the control of the respective fungi has not been tested exhaustively in any locality. It seemed worth while also to study the value of certain indirect methods of checking disease losses, such as changes of rotation and sanitation.

Experimental results obtained cover work from 1919 to 1926, inclusive, mostly conducted under practical farm surroundings and involving particularly various methods and conditions in the use of formaldehyde and other disinfectants on lettuce seedbeds in coldframes. Concurrently, laboratory and garden studies were made of the efficiency of the disinfectants in killing sclerotia under different conditions and at varying depths in the soil.

Seedbed Sterilization With Formaldehyde

At Bustleton, seedbed treatments with formaldehyde, as well as other disinfectants, were performed chiefly in late September or early October. Plots known to be badly infested by *Sclerotinia sclerotiorum* were always selected for experimental purposes, as the main object was to test the power of the disinfectants in killing the sclerotia. Considerable care was always used in the selection of check plots that were as badly and as uniformly infested as those intended for treatment. Until 1924, little attention was given to the moisture content of the soil at the time of treatment, except that very damp soil was avoided. Usually the soil was comparatively low in moisture and in some cases, as will be shown, doubtless too dry for the most effective results with formaldehyde against *S. sclerotiorum*.

Strengths of the Solution and Methods of Application

Since the first use of formaldehyde as a soil disinfectant, for the purpose of greater efficiency there has been considerable increase in the strength of the solutions applied. Stevens (19) tried 1-400 strength of the commercial material with little control of *S. sclerotiorum*, while Johnson (7) found 1-50 necessary to control Rhizoctonia and Pythium. The data of Krout (9), which have been corroborated in some respects at Bustleton, show that 1-100 strength, applied at the rate of a gallon to the square foot, assures satisfactory control providing the sclerotia within the soil are in a moist condition. Some good results were obtained at Bustleton with weaker solutions (Table I). Although, on the other hand, certain treatments with 1-100, or the equivalent of this strength, were not sufficiently effective, the high cost of the formalin has been a deterrent in using any greater amount of the disinfectant on a given area of soil, especially since it became evident that there are factors other than the strength of the solution determining the efficiency of a treatment.

The expeditious application of formaldehyde in a strength as great as 1-100 at considerable distances from the source of water and during a season when other farm

operations require attention presents a measure of difficulty. While transporting water by hose or irrigation lines is usually possible, the preparation of large quantities of solution in tanks from which gravity can aid in carrying the liquid to the seedbeds requires special apparatus not readily available. In most of the seedbed treatments, therefore, solutions were mixed in barrels and watering pots were used to spread them over the soil. This process required much time and labor when large areas were to be treated with the 1-100 strength in the customary way.

Aiming to overcome the excessive hand labor and consumption of time and using only the apparatus possessed by the average trucker, experiments were undertaken in which smaller proportions of water were used for diluting the formalin, thus reducing the amount of solution to be passed through the watering pots. Instead of 1-100, strengths of 1-8, 1-16, 1-25. 1-33, and 1-50 were tried, with attention to the application of the quantity of formalin required for the surface of the soil (Table I). If such solutions were used alone, the surface soil would receive a strong disinfection and the deeper strata little or none depending on the amount of solution. In order to carry the formaldehyde more deeply, water was added from a hose, or sometimes by (Skinner) irrigation,* until the soil was saturated to the cultivated depth. It was deemed advisable to reserve a portion of the formaldehyde for application after the addition of water alone.

Subsequent Care of Treated Seedbeds

The older literature recommended the covering of the surface of seedbeds with burlap after treatment with formaldehyde. This was not done at Bustleton because the areas were unusually extensive. Studies of the killing action of formaldehyde upon sclerotia (Table V) indicate that the covering is important only when the soil is light and dries out quickly. Recent papers (9, 13) do not prescribe this covering of the treated soil.

In the open, the escape of the formaldehyde gas from the treated soil was sufficiently rapid that it did not interfere with successful planting. The shortest period between treatment and seed sowing in the present work was eight days, and the only effect on germination was a considerable retardation. Usually the soil was cultivated about three days after treatment and then again as the soil was raked level for sowing. The data of Tables III to V indicate that a heavy soil like that at Bustleton retards the thorough diffusion of the disinfectant, and there would appear to be some benefit in leaving such soils undisturbed as long as possible after treatment.

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*According to the statement of Professor Webster S. Krout of The Pennsylvania State College, Skinner irrigation has been used in some trucking sections to apply 1-100 strength of formaldehyde to soil.

Another apparatus that is adapted for the application of a solution or a mixture of any disinfectant in water in a constant proportion consists of a pressure regulator, a water meter, a specially made injector and a tank to contain the disinfectant. Water must be obtained from a system under pressure, and some form of nozzle is needed to spread the solution. Such an apparatus is described by B. R. Leach, Control of Japanese Beetle in Lawns, General Bulletin No. 410, Pennsylvania Department of Agriculture, Harrisburg, 1925.

Experimental Results

Results with formaldehyde, covering a variety of conditions during a period of seven years, are recorded in Table I. The average prevalence of *Sclerotinia sclerotiorum* on lettuce maturing on untreated sash soil set apart as checks during this period was 15.9 ± 1.4 per cent, while the average prevalence on the various treated plots was 4.05 ± .6 per cent or a reduction of 11.85 per cent. Although this degree of control compares favorably with the results of Krout (9), which show a reduction of drop to average losses of 2 to 4 per cent, it may be noted from Table I that some instances of relatively poor control enter into the average per cent. These less successful results are confined mostly to the variety Dutch Butter, which is grown for the earlier spring market, is brought to maturity before the removal of sash, and is inherently very susceptible to drop. Experiments involving this variety are marked "X". All other treatments involved the varieties Big Boston or Eberle's Ideal, of which sowings were made primarily for seedlings to set in the field in spring, though a stand was always left to mature on the seedbeds. The data given in Table I concern the disease losses in these stands left on the seedbeds.

It appears probable that the amount of disease would be less on the treated plots were the lettuce grown to maturity without the interval of arrested growth in winter, for Sclerotinia and Botrytis develop appreciably during this interval. The only data on this point are those of experiment 1923 *d*, Table I, in which the green crop, *Valerianella locusta*, or corn salad, was grown. This crop is sown in September and matures in December. It covers the soil and is especially susceptible to attack by *Sclerotinia sclerotiorum*. With this crop a loss of 40 per cent was reduced to .3 per cent by formaldehyde. Yet in the case of 1923 *cx* on similarly infested soil treated at the same time, *S. sclerotiorum* caused five per cent loss in Dutch Butter lettuce the following spring.

TABLE I

The Control of Lettuce-Drop in Cold-frames and Other Experimental Plots with Formaldehyde

Experiment	Dilution of 37% solution	Quantity to one sq. ft.	Extra water supply	Number of plants on treated areas	Per cent of drop on treated areas	Number of plants on check areas	Per cent of drop on check areas	Remarks
1919 a	1-160	2/3 gal.		270	0	270	3.2	Spring garden
1919 b	1-160	2/3 "		270	0	270	10.3	Fall garden
1920 a	1-133	1 "		205	8.8*	1000	23.8	Field, **S. Minor**
1921 a	1-133	1 "		275	.3	1000	8	
1922 a	1-100	1 "		800	2.5	1100	22	
1922 bx	1-40	2/5 "	.2 in. rain	1700	11	1700	20	
1922 c	1-33	1/3 "	.35 " "	3900	3.5	1950	34	
1923 a	1-100	1 "		750	3	1500	7-35	
1923 bx	1-33	1/3 "	.3 " "	2000	7	1900	16-24	*S. sclerotiorum*
					10		23-36	*Botrytis sp.*
1923 cx	1-25	1/4 "	Hose	2100	5	1900	16-24	*S. sclerotiorum*
					7		23-36	*Botrytis sp.*
1923 d	1-16	1/6 "	Irrigation	2100 sq. ft.	.3*	450 sq. ft.	40	Valerianella locusta grown
1924 ax	1-16	1/6 "	Hose	750	11	750	14	Soil not loosened in treatment
1924 bx	1-16	1/6 "	Hose	750	4.5	750	14	Soil loosened in treatment
1924 c	1-16	1/6 "	Hose	750	6	750	6	Soil not loosened
1924 d	1-8	1/12 "	2.59 in. rain	27000	3.5	1400	5.5	*S. sclerotiorum*
					25.3		30.3	*Botrytis. sp.*
1925 a	1-16	1/6 "	Hose	300	0	700	5.2	
1925 b	1-33	1/3 "	Hose	300	0	700	5.2	
1925 c	1-50	1/2 "	Hose	700	.3	700	5.2	
1925 d	1-25	1/4 "	Hose	900	.2	700	5.2	Part of formaldehyde applied in furrow
1925 ex	1-25	1/4 "	Hose	1080	8	1080	10.5	Part of formaldehyde applied in furrow
Average prevalence of *Sclerotinia sclerotiorum*,								
1. All experiments				44595	4.05±.3	19120	15.9±1.4	
2. Solutions of 1-100 (or weaker)				2365	1.83±.44	4140	16.2±3.04	
3. Solutions stronger than 1-100 with subsequent addition of water				42230	4.18±.79	14980	15.7±1.5	

Averages = weighted arithmetic mean.
*Omitted from averages.

In those experiments in which formaldehyde was spread with subsequent addition of water alone, the average reduction of disease is 11.5 per cent as compared with 14.37 in cases in which the disinfectant was applied in 1-100 dilution. The varied nature of the experiments would make a greater number of trials necessary in order to ascertain whether this is the true margin of difference, inasmuch as the results in Table III recording studies of the killing action of formaldehyde upon sclerotia do not exhibit consistent differences opposed to the applications in dilutions less than 1 100. Attention may be directed again to the success of the experiment with the corn salad, 1923 *d*, Table I, in which the strength of the formalin was 1 16 and the additional water was applied by a Skinner irrigation system.

In favor of the application in low dilution is its great convenience if labor-saving means of applying the 1 100 strength are not available. It is possible for two men working together equipped with two barrels and two 3 gallon watering pots, one man directing the hose and the other spreading the solution, to treat the space for 200 to 300 sash a day. In practice, it may be advisable to use the formalin in the proportion of 1-25 as this provides enough solution to moisten the soil to a depth of approximately three inches before the addition of water, thus saving possible evaporation. This strength has the further convenience of providing 4.5 gallons of solution for a 3 by 6-foot sash area, 3 gallons of which may be applied at the beginning and 1.5 gallons after the addition of water.

In experiment 1924 *d*, an attempt was made by a grower to treat a considerable area just prior to a rain, using 1 8 strength. While *Sclerotinia sclerotiorum* was not a great factor, it appears that the excessive rainfall with a great deal of run off largely dissipated the disinfectant. On the other hand, experiments 1922 *e* and 1923 *bx* in which rainfall provided the additional water showed comparative success, although in these cases the formalin was applied in 1-33 strength and the rainfall was less than was considered desirable.

Some results upon the relation of a loose condition of the soil are shown in experiments 1924*ax*, 1924 *bx*, and 1924 *c*, Table I. In 1924 *ax*, no attempt was made to reloosen the soil, which had been prepared for a considerable time as a seedbed and had been packed somewhat by rain. Drop was reduced but three per cent, or from 14 to 11 per cent. In 1924 *bx*, the soil was loosened in the course of treatment to aid the penetration of the solution and in this instance drop was reduced from 14.5 to 4.5 per cent. In 1924 *c*, the soil was not loosened and no control was obtained, although disease was a small factor, causing only six per cent loss. The uniform success of experiments 1919 *a*, 1919 *b*, 1920 *a*, 1921 *a*, and 1922 *a* probably depend considerably upon the fact that the soil was well worked over in the course of treatment to aid the penetration and thorough distribution of the solution. In the subsequent experiments on a greater scale, such working of the soil was not so well done. Examination of the penetration in a firm soil like that in experiment 1924 *ax* by employing only the rough method of following the line of wetting showed that the failure of the treatment lay largely in unequal depth of penetration in different rows. This fact is also indicated by the variable killing action of formaldehyde according to depth shown in Tables III, IV, and V.

PLATE II.

Fig. 3.—Lettuce Growing on Diseased Soil. Certain of the Plants are Infected by Rhizontonia solani.

Fig. 4. Lettuce Growing on Soil Sterilized with Formaldehyde. Sowing was Done at the Same Time as in Fig. 3. The Increased Growth is Caused Partly by "Stimulation"

Growth Effects

The germination of lettuce seed in soil treated with formaldehyde commonly showed retardation, but in time plants on treated soil developed beyond those of the checks, indicating possible stimulation, increased fertility, or freedom from soil parasites. The retardation was greater when the period between treatment and sowing was brief, being particularly prominent when the period was only eight days. Comparative growths on treated and untreated plots are typically illustrated in Plate II, although in Fig. 3 evidence was found that the more backward plants were attacked by *Rhizoctonia solani*. Usually the improved growth is a benefit, but in 1924, on account of advanced growth of all lettuce seedlings during the previous fall, plants on treated soil became especially susceptible to frost and consequently suffered greater damage by *Botrytis sp.* than did many of the checks. Enhanced size and quality of the lettuce on treated soil are marked, as a rule, especially near the market stage, Plate I, Fig. 2.

Improvement in the Stand of Transplanted Lettuce

As a result of formaldehyde treatment, a greater gain has been realized on the transplanted crop of lettuce than on that matured on the sash soil. The increased vigor and health of the seedlings seem to enable them to undergo transplanting with less loss. The gain is mostly in the elimination of *Botrytis sp.* and *Rhizoctonia solani* which appear at various stages prior to maturity (Table II). Every year, except 1924 when the January freezing of unusually large and tender seedlings paved the way for widespread Botrytis infection, there were substantial increases in the number of plants attaining marketable size free of disease. The results vary widely, being affected, no doubt, by weather factors, but the average improvement for a 6-year period is 14.1 ± 3.6 per cent, or an average of 88.5 per cent stand with seedbed treatment compared with an average of 74.4 per cent stand without seedbed treatment. This gain, which is more than three times the probable error, is based on tenfold the size of the necessary seedbed, and affords the basis of a good profit in seedbed sterilization.

TABLE II

Results on the Stand of Transplanted Lettuce from Formaldehyde-Treated and Untreated Seedbeds.

Year	Source of seedlings	Number of plants counted	Per cent of total that were healthy at maturity	Yearly average per cent gain	Per cent dying from *Sclerotinia s. lecticorum*	Per cent dying from *Botrytis*, large plants	Per cent dying soon after transplanting from *Botrytis*, *Rhizoctonia*, or unknown fungi
1921	Treated seed bed	1550	93.9	11.6	1.9	1.6	2.6
	Untreated seed bed	1550	82.3		1.5	7.1	9.1
1922	Treated seed bed (a)	5700	89.2		.02	1.6	9.14
	" " " (b)	2280	94.5				
		7980	90.7	27.2			
	Untreated seed bed (a)	2280	76.4		2.3	3.5	17.8
	" " " (b)	2280	50				
		4560	63.2				
1923	Treated seed bed	2050	92.9	31.4	.3	3.2	3.6
	Untreated seed bed	2050	61.5		.5	15.3	13.5
1924	Treated seed bed (a)	1900	87.8		.2	4.6	7.4
	" " " (b)	1000	69		0	6.3	24.7
	" " " (c)	768	59		.4	11	29.6
		3668	78.6	— .6			
	Untreated seed bed (a)	2280	87.8		.1	5	6.2
	" " " (b)	1000	65		0	7	28
	" " " (c)	773	59		.5	10	29.6
		4053	77.2				
1925	Treated seed bed (a)	1460	89.5		.3	3.3	6.7
	" " " (b)	1500	91				
		2960	90.2	9			
	Untreated seed bed (a)	3400	81		1	8.1	10.6
	" " " (b)	1500	88				
	" " " (c)	1500	75				
		6400	81.2				
1926	Treated seed bed	350	98.4	9.1	0	.32	1.28
	Untreated seed bed	660	89.3		0	1.8	8.9
Six year average	Treated seed bed	18558	88.5±2.5				
	Untreated seed bed	19273	74.4±2.6	14.1±3.6			

N. B. Per cents are based on the total number of seedlings transplanted, or a perfect stand, and the averages equal the weighted arithmetic mean.

PLATE III.

Fig. 6.—Application of Formaldehyde Solution to Lettuce Seedbeds in Cold-frames with the Aid of Portable Skinner Irrigation.

Fig. 7. Lettuce Seedling Bed Severely Attacked by Botrytis. Too Thick Sowing, Rapid Growth and Frost Injury Predisposed the Plants.

Effect of Formaldehyde Treatment Upon Botrytis

In experiments 1923 *bx*, 1923 *cx*, and 1924 *d*, Table I, a certain degree of control of Botrytis is shown. This control is partly indirect on account of the earliness and vigor of the crop on treated soil. Since earlier cutting is possible, some loss by Botrytis is avoided. It appears probable, however, that a measure of this control is brought about by the destruction of the sclerotia and the spores of Botrytis in the soil and on the boards of the frames. When lettuce becomes particularly predisposed to Botrytis infection, through the effects of adverse weather factors, sterilization of seedbeds has little or no effect in checking the disease (Plate III, Fig. 7).

The periodic damage by Botrytis in seedbeds receiving sterilization may prove a handicap in the extension of the process. A great deal of loss by Botrytis, however, is due to improper regulation of cultural conditions. The sash should be sound and tight to prevent frost injury, and great attention should be given to ventilation on bright warm days to prevent too high temperatures and the precipitation of moisture when cooling follows. Greatly forced crops are more susceptible than those in which slow growth occurs. Relatively thin sowing affords some reduction of loss in seedling beds. The chief factors in predisposing lettuce under glass to Botrytis infection appear to be the alteration of great temperature extremes combined with rapid and succulent growth.

Killing Effect of Formaldehyde Upon Sclerotia under Varying Conditions

In general, formaldehyde has shown less effectiveness in killing sclerotia of *Sclerotinia sclerotiorum* in experiments conducted in Bustleton garden soil than in the experiments reported by Krout (9) for the soil of the Massachusetts greenhouses, this effectiveness being ascertained by testing the viability of the sclerotia on agar plates following soil treatment. In accounting for the difference in results two factors should be considered. There may have been an effect due to the work having been done in the open at Bustleton, and the heavy character of the Bustleton soil as compared with the more porous soil in the Massachusetts greenhouses doubtless is also a factor of importance.

PLATE IV.

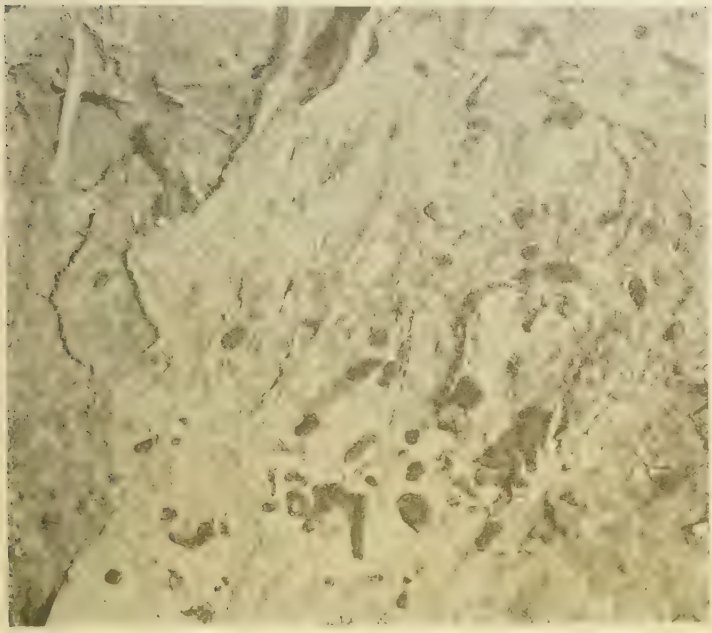

Fig. 5. Sclerotia of Sclerotinia sclerotiorum Remaining upon the Soil after the Decay of Lettuce, Celery, or Carrots

TABLE III

The Killing Action of Formaldehyde upon the Sclerotia of *Sclerotinia sclerotiorum* according to Depth in the Soil and the Strength of Applying the Disinfectant.

Depth	Dilutions of the formalin						Totals according to depth	Per cent not killed according to depth
	1-100 a	1-100 b	1-50	1-33	1-16	1-8		
Surface	1/10	0/12	0/10	1/10	0/11	0/14	2/67	3.%
3 inches	5/16	1/10	2/10	1/12	1/15	2/14	12/78	15.4
* 4.5 "	6/14	6/16	6/12	4/12	4/14	5/12	31/80	38.7
6 "	0/14	3/6	3/12	5/12	3/17	0/15	14/76	18.4
9 "	2/15	0/9	4/10	2/11	1/15	4/10	13/70	18.5
12 "	0,15	4/10	5/11	3/12	2/16	0/11	14/75	18.6
Totals according to dilutions	14/84	14/63	20/65	16/70	11/88	11/76		
Per cent not killed according to dilutions	16.6%	22.2%	30.7%	22.8%	12.5%	14.4%		

* The sclerotia placed at 4.5 inches depth had been soaked in water 24 hours, while those at other depths had been soaked 48 hours.

N. B. Tested by mycelial germination on agar, sclerotia possessed at least 54 per cent viability prior to treatment; sclerotia remained in the treated soil 2 to 3 days.

Denominators indicate the number of sclerotia tested and numerators the number remaining alive.

TABLE IV

The Killing Action of Formaldehyde upon the Sclerotia of *Sclerotinia sclerotiorum* according to Depth in the Soil and the Strength of Applying the Disinfectant.

Depth	Dilution of the formalin					Totals according to depth	Per cent not killed according to depth
	1-100	1-50 a	* 1-50 b	1-33	1-16		
Surface	0/15		0/15			0/30	0%
3 inches	0/15	5/15	7/15	0/15	0/15	12/75	16.
4.5 "	6/13	0/15	13/17	10/16	4/15	33/76	43.4
6 "	4/15	12/16	14/17	5/16	3/15	38/79	48.1
9 "	5/15	2/16	12/16	8/15	13 15	40/77	51.9
12 "	8/15	6/15	16/26	0/13	12/16	42/84	50.
Totals according to dilution	23/88	25/77	42/84	23/75	32/76		
Per cent not killed according to dilution	26.1%	32.5%	56.5%	30.6%	42.1%		

*In the case of this 1-50 dilution no pure water was added to the soil.

N. B. Tested by apothecial germination, sclerotia possessed at least 80 per cent viability prior to treatment; sclerotia remained in the treated soil five days.

Denominators indicate the number of sclerotia tested and numerators the number remaining alive.

TABLE V

The Killing Action of Formaldehyde upon the Sclerotia of *Sclerotinia sclerotiorum* according to the Depth in the Soil and the Dampness of the Sclerotia.

Column	1	2	3	4	5	6
Depth	Sand, Sclerotia dry	Sand, sclerotia dampened	Sand and clay sclerotia fresh	Soil sclerotia dampened	Soil sclerotia fresh	Soil, 1-25 dilution instead of 1-100, extra water
Surface	7/15	8/13	3/15	0/20	0/15	0/15
1 inch	3/15	5/16	1/15	0/14	0/15	1/15
2 "	7/15	0/18	0/14	0/13	1/15	
3 "	8/14	4/15	0/17	4/15	0/16	0/14
4 "	14/16	3/14	0/15	0/15	0/15	1/15
5 "	9/17	3/16	0/15	0/16	1/15	0/15
6 "	8/16	0/15	1/15	1/16	2/14	1/15
9 "	7,17	3/15	1/15	2/17	0/15	1/15
12 "	9/15	6/14	0/15	4/15	3/17	0/15
Total	72/140	32/136	6/136	11/141	7/137	4/118
Per cent not killed	51.4%	23.5%	4.4%	7.7%	5.1%	3.4%

N. B. Tested by mycelial germination; sclerotia remained in treated soil seven days

Denominators indicate the number of sclerotia tested and numerators the number remaining alive.

In a number of preliminary trials with formaldehyde, it was found to be the usual case that 1-100 strength, also 1-133, was sufficient to destroy sclerotia buried in pots of sand at depths varying from the surface to four inches. In these trials, the test of viability was subsequent germination *in situ*, with formation of apothecia, or occasionally mycelium, in the laboratory or a shaded situation. Such experiments were often repeated as checks against other chemicals (Table IV), 200 to 300 sclerotia being placed in an 8 inch flower pot. Untreated sclerotia tested in this manner normally gave a copious number of apothecia. The results were in apparent agreement with those of Krout showing that 1-100 strength would entirely prevent germination under the stated conditions.

More detailed experiments with Eastleton garden soil consisted of placing sclerotia in small sacks of bolting cloth (except for the data in the third, fifth, and sixth columns of Table V, where wire baskets were used) and burying these at various depths from the surface to 12 inches. The sclerotia were relatively large in size, such as those that may be collected from celery and carrots affected with the soft watery storage rot. Since these usually become thoroughly dry before use in experiment, they were allowed to imbibe moisture again by being kept a day or two in water or in moist soil prior to treatment.

The experiments in testing the efficiency of formaldehyde at varying depths also embraced tests in applying the disinfectant in different dilutions less than 1-100 enough pure water being added subsequently to make a gallon to the square foot (Tables III and IV.)

When the sclerotia had been recovered from the soil, they were washed in sterile water, in some cases given brief surface treatment with mercuric chloride or hydrogen peroxid, cut in two parts, again washed in sterile water, and finally placed on poured petri dishes of corn meal agar. The results in Tables III and V were obtained in the spring and only mycelial germination occurred, but in Table IV the results were obtained in late fall when the temperature happened to favor good apothecial production in an unheated room. The two methods of germination furnished essentially similar data. It may be pointed out that per cents "not killed" are based on the total number of sclerotia rather than on the number of these originally viable. Viability prior to treatment varied in the different trials.

In ascertaining viability in the checks, it was considered essential to test the effect of keeping sclerotia in untreated soil during the period of the treatments. In late spring and summer, this was found to affect germination on agar in an important way, as the sclerotia became infected by other fungi and bacteria and decayed during the test for viability. For this reason data obtained in warm weather had to be discarded, for although the formaldehyde tended to prevent this foreign infection, it did not entirely do so. The 54 per cent viability given in Table III and the 80 per cent given in Table IV are those of sclerotia kept during the period of the treatin untreated soil. In Table V, the sclerotia were either fresh, or quite recently collected from diseased lettuce, and were presumed to have a high state of viability.

The outstanding feature of the data in Tables III, IV, and V is the incompleteness with which the sclerotia are killed and the variable nature of the results with respect to depth, although a high degree of efficiency is exhibited near the surface. Unless the sclerotia are injured enough to make subsequent decay more probable than germination, it does not appear that formaldehyde treatments of the seedbeds can benefit more than one crop in a satisfactory manner, since sclerotia not killed will be brought to the surface at the next plowing. Taking into account, however, the tendency to decay noted in the sclerotia tested in pots of sand following treatment, it appears that severing the sclerotia and placing them on agar gives much better chances for traces of viability to develop than would be the case in soil. A disposition to decay following injury by the disinfectant and the high degree of complete killing near the surface, where alone the sclerotia are able to germinate in nature, are no doubt the bases of the control obtained in the seedbeds.

When an explanation is sought for the variable killing action according to depth, it seems fair to assume that the strength of the solution is sufficient in the light of the data of Krout (9) and the results obtained when the solution makes ready contact with the sclerotia. Respecting the penetration of formaldehyde in soil, Hunt, O'Donnell and Marshall (6) report that the penetration of this disinfectant is apparently equal to that of the water carrying it in solution even in dilutions of 0.05 per cent of the commercial solution. Accepting this as fact, failure of thorough disinfection would depend mostly upon uneven or incomplete distribution of the solution through the soil. Such uneven distribution would appear to be a particular difficulty in a heavy soil or one containing a large proportion of clay. To overcome this difficulty, the soil may be thoroughly loosened prior to treatment and then hoed

or spaded over after a portion of the disinfectant is applied. With the experiments in Tables III, IV, and V, the soil was probably more thoroughly loosened or pulverized than would be common in coldframes, but it was not practicable to stir the soil after the application of the solutions. This lack of stirring possibly caused some of the erratic results, especially within the deeper lying strata.

A partial explanation of the failure of the sclerotia to be killed at 9 and 12 inches depth is the data of Hunt, O'Donnell and Marshall (6) showing that a gallon to the square foot, the amount of solution always used in the experiments of Tables III, IV, and V, is insufficient to reach these depths, except occasionally.

The treatments in sand in the garden, Table V, were low in efficiency apparently because moisture and the disinfectant were rapidly lost, indicating that the presence effects the death of the sclerotia slowly. A small proportion of clay added to the sand aided the retention of moisture and increased the degree of kill, especially near the surface. The results with sand in the garden differed from those in pots of sand in the laboratory previously mentioned because the pots were kept in a situation where drying was largely prevented or occurred slowly.

Comparing the efficacy of the different dilutions or strengths in which the formalin was applied, the data of Tables III, IV, and V do not show any striking association or consistently in favor of the 1-100 strength or opposed to the great strengths with the subsequent addition of water. If there is anything essential, it is greatly outweighed by the other factors promoting efficiency; namely, looseness or friableness of the soil, stirring the soil to acquire even distribution of the solution, and a damp condition of the sclerotia.

The importance of a damp condition of the sclerotia, or the condition resulting from considerable imbibition of water, in increasing the per cent of kill is brought out by comparing results in the first and second columns of Table V. In the case of air-dry sclerotia in sand 72 out of 140 failed to be killed, while in the case of the damp sclerotia in sand only 32 out of 136 failed to be killed, or 51.4 per cent compared with 23.5 per cent. It appears probable that too dry a condition of the sclerotia was a factor in some cases of poor control given in Table I, notably 1923 *bx*, and 1923 *cx*, as these treatments were preceded by a long drought. Fresh or recently formed sclerotia that have never become air-dry appear to be readily killed (Column 5, Table V).

Cost and Profit in Formaldehyde Sterilization

In computing the cost of formaldehyde sterilization, it is convenient in the case of coldframes to use one sash area as a unit. This area of 18 square feet, a space sufficient for 32 mature lettuce plants as commonly grown, requires 1.4 lbs. of formalin, or approximately 1.4 pints, costing 21 cents based on average prices. The labor cost varies with circumstances, but the method of application largely employed at Bustleton has made the cost of labor approximately four cents a sash. It is unlikely that any appreciable economy in [illegible] appreciably, while the cost increases greatly if all the water is applied by watering pots. It appears, therefore, that [illegible] a sash.

The profit in treatment is difficult to compute on account of the widely varying prices of lettuce. From 1918 to 1925, however, the sash crop sold at relatively high prices, ranging from 6 to 12 cents a head. At the lower price, an average increase of 11.85 per cent of marketable lettuce obtained in the sash alone would scarcely meet the cost of the treatment, as this increase represents only 3.8 additional heads. Consideration, however, may be given to the earliness, weight and quality of the crop, which are commonly significant and enable the best prices to be obtained. Moreover, if the treated soil is used as a bed for seedlings as well as to mature a crop, a liberal margin of profit is assured, for all the gain in the transplanted crop is clear. Assuming roughly that the seedbed area will provide seedlings for tenfold as great an area in the open, the 14.1 ± 3.6 per cent gain in stand in the transplanted crop would assure a profit of approximately $2.50 for each sash area treated, if the computation is based upon the average prices obtained for the transplanted crop.

Effects of Certain Disinfectants Other than Formaldehyde Upon the Viability of Sclerotia of Sclerotinia sclerotiorum and Upon the Growth of Lettuce

In seeking a control agent for lettuce "drop" that would be cheaper, more expeditiously applied and possibly more effective than formaldehyde or heat sterilization, a considerable number of chemicals or fungicides were tested for their power to kill sclerotia in soil and at the same time not be injurious to the crop or too costly. With respect to lettuce, none of the compounds tested has offered great promise of meeting the requirements, although a few are worthy of further trials in strengths different from those thus far employed. In general, sclerotia of *Sclerotinia sclerotiorum* appear difficult to kill in soil by disinfectants, and for this reason there has been a disposition to overdose, resulting in many cases of injury to the crop and few instances of improvement or crop "stimulation" such as is reported by Miege (11).

TABLE VI

The Effects of Certain Disinfectants upon the Viability of the Sclerotia of *Sclerotinia sclerotiorum* and upon the Growth of Lettuce in Comparison with Formaldehyde.

Disinfectant	Strength of solution and quantity to the square foot	Situation of sclerotia	Effects on viability of sclerotia	Effects on the growth of lettuce
Lime sulphur	1-10; 1 gal	Potted sand	Failed to germinate	Serious injury
" "	1-40; ½ gal	Garden plot	" " "	" "
" "	1-40; 3 gal	Potted sand	" " "	Some injury
Mercuric chloride	1-5000; 1 gal	" "	Abortive apothecia	Retarded (garden plot)
" "	1-4000; 1 gal	" "	Few abortive apothecia	Injury
Copper sulphate	1-834; 1 gal	" "	Failed to germinate	Injury
" "	1-550; ½ gal.	Garden plot	Imperfect apothecia	Injury
" "	1-1390; 1 gal.	Potted sand	Few normal apothecia	Slight injury
" "	1-417; 1 gal.	Garden plot, limed	" " "	Retarded
Ferric chloride	1-167; 1 gal.	Potted sand	Normal apothecia	No apparent injury
" "	1-83; 1 gal.	" "	Germination lowered	" " "
Sulphuric acid	1-70; ½ gal.	Garden plot, limed	Few imperfect apothecia	Slight injury
" "	1-70; ½ gal.	Potted sand	Failed to germinate	Severe injury
" "	1-104; ½ gal.	" "	" " "	" " "
" "	1-208; 1 gal.	Garden plot, limed	" " "	Good growth
Ferrous sulphate	1-167; 1 gal.	Potted sand	Much reduced germination	Slight injury
"	1-208; 1 gal.	" "	Reduced germination	" " "
" "	1-140; 1 gal.	" "	Few apothecia	" " "
Barium chloride	1-83; 1 gal.	" "	Reduced germination	Injury
Chlorinated lime	1 lb. to 25 sq. ft.	Garden plot	Few apothecia	No apparent injury
" "	1 lb. to 10 sq. ft	Potted sand	Much reduced germination	" " "
Potassium permanganate	1-3785; 1 gal.	" "	Slightly reduced germination	" " "
Sulphur	10 gms to 1 sq. ft.	" "	Few abortive apothecia	Injury
Wood alchohol	20 %; 1 gal.	Potted sand	Germination reduced	" " "
Potassium sulfid	1-280; 1 gal.	" "	Many apothecial stalks but few normal discs	Little apparent injury
Calcium chloride	5 % solution; 1 gal,	" "	Slightly reduced germination	" " "
Cleaning solution	1-10; 1 gal.	" "	Failed to germinate	Injury
" "	1-30; 1 gal.	" "	" " "	Injury
Pyroligneous acid	1-10; 1 gal.	" "	" " "	" "
Kerosene	1 gal. to 33 sq. ft.	" "	" " "	Severe injury
"	1 gal. to 50 sq. ft.	Garden plot	" " "	" " "
Sulphur bloom	80-20 mixture; ½ oz.	Potted sand	Failed to germinate	" " "
" "	60-40 " ; ½ oz.	" "	Apothecial stalks but imperfect discs	Injury
" " "	80-20 " ; ½ oz.	Garden plot	" " "	Severe injury
Bordeaux mixture	4-4-50; 1 gal.	Potted sand	Numerous apothecia	Slight injury
Sodium hydrogen sulphate crude	1-100; ½ gal.	Garden plot	Apothecial stalks but no discs	Severe injury
Picric acid	1-208; ½ gal.	" "	Failed to germinate	Severe injury
"	1-1670; 1 gal	Potted sand	Apothecial stalks but few and small discs	Lettuce seed germinated normally
Crude cresol	1-66; ½ gal.	Garden plot	Few apothecial stalks	Severe injury
" "	1-200; 1 gal.	Potted sand	Failed to germinate	" " "
Crude carbolic acid	1-100; 1 gal.	" "	" " "	" " "
Semesan	1 oz. to a sq. ft.	" "	Apothecia produced	" " "
"	½ oz. to a sq. ft.	" "	Germination reduced	" " "
"	¼ oz. to sq. ft	" "	A very few apothecia	" " "
Hot formaldehyde	1-400 boiling water; ½ gal	Garden plot	Failed to germinate	Normal growth
"	1-400 boiling water; 1 gal.	Potted sand	" " "	" " "
" "	1-200 boiling water; ½ gal.	Garden plot	" " "	" " "
Formaldehyde	1-160; 1 gal	" "	A few apothecia	" " "
"	1-133; 1 gal.	" "	Two sclerotia germinated	" " "
"	1-100; 1 gal.	" "	Failed to germinate	" " "
"	1-80; 1 gal.	" "	" " "	" " "

Semesan, Uspulun, and Bayer Compound have shown minor improvement or "stimulation" in lettuce seedbeds, but in these cases the applications were made below the amount shown to be necessary to kill the sclerotia. Injury to the crop by these organic mercury compounds appears to have some relation to the dampness of the soil. In 1924, Semesan at the rate of one-half ounce to the square foot (this amount being that found necessary to prevent all but a fraction of one per cent of germination in sclerotia placed in potted sand), produced no apparent injury to lettuce when incorporated in the seedbed as a dust, but in 1925, this amount prevented proper heading on the seedbed, although the plants moved to the field showed good quality and the stand was four per cent better than the check. The only variable factor of importance between the two years was the fact that the soil was relatively wet throughout the period of October, 1923, to April, 1924, while during the period of October, 1924, to April, 1925, the soil was unusually dry when treated, as also during a considerable period of the fall and again during a large part of the spring.

In one instance sulphuric acid, 1-208 applied at the rate of a gallon to the square foot and followed by liming, gave a noteworthy improvement in the growth of lettuce but no data were obtained with respect to disease control. In other trials, sulphuric acid showed efficiency in killing sclerotia, and it seems probable that careful liming can prevent injury to the crop. The necessity of two operations in the treatment is somewhat disadvantageous.

Attention may be called to the negative results with Bordeaux mixture and copper sulphate, since these materials have been recommended for drenching the soil following re-seeding (19). While it is probable that they can destroy mycelium, they do not prevent the germination of the sclerotia nor prevent the spread of "drop" when infection is abundant.

TABLE VII

The Effects of Certain Disinfectants in Reducing Lettuce-Drop Caused by *Sclerotinia sclerotiorum*, and the Effects on the Growth of Lettuce.

Disinfectant	Strength of solution and quantity to the square foot	Disease on treated plots	Disease on untreated plots	Effects on the growth of lettuce; remarks
Bordeaux mixture	4-4-50; 1000 gals. to acre, seedling stage	6 %	8 %	Normal, field
" "	4-4-50; ½ gal. applied after sowing	35-40	25-40	Normal, cold frame
" "	4-4-50; ⅛ gal. applied after sowing	9	5-16	" " "
" "	4-4-50; 1 gal. on seed bed.	28	24	" " "
" "	4-4-50; 1875 gals. to acre, seedling stage	15	15.6	Normal, field
" "	8-8-50; heavy application about large plants	31	31	" "
" "	8-8-50; heavy application about large plants	30	30	" "
Copper sulphate	1-300; ¼ gal.	35-40	35-40	Normal, cold frame
" "	1-417; ¼ gal.	13	5-16	" " "
" "	1-1669; 1 gal.	37	24	" " "
" "	1-417; ¼ gal.	1.5	11.6	Injurious, garden, summer
Barium chloride	1 lb. to 20 sq. ft.	7	5-16	Injurious (?) cold frame
" "	1 lb. to 20 sq. ft.	?	35-40	Very injurious, cold frame
Crude carbolic acid	1-50; 1 gal. to 14 sq. ft.	14.7	15.6	Injurious, field
Ammonical copper carbonate	5 gals. to 100 sq. ft.; standard spray	30	30-40	Normal, cold frame
Crude cresol	1-50; ¼ gal.	15	5-16	Injurious, cold frame
Cynnamid	1 lb. to 20 sq. ft.	4.7	7-8	" " "
Ferric chloride	4 lbs. to 150 sq. ft.	8	5-16	Normal, cold frame
Ferrous sulphate	1-83; ¼ gal.	17	16	" " "
" "	1-83; ½ gal.	11.7	38	Injurious, field, **S.minor**
" "	1-167; 1 gal., limed	24	24	Normal, cold frame
Mercuric chloride	1-5000; ¼ gal.	6	6-8	No injury, cold frame
" "	1-2000; ½ gal.	0	11.6	Severe inj., garden, summer
" "	1-4000; 1 gal.	—	—	" " " "
Sulphuric acid	1-42; 1/10 gal., limed	4	5-16	No injury, cold frame
" "	1-46; ⅛ gal. limed	6-8	6-8	" " " "
" "	1-167; 1 gal.	—	——	Temporary injury, cold frame
Sulphur	1000 lbs. per acre; dusted around plants	10-12	38	Injurious, field, **S.Minor**
Potassium sulfid	1-250; 3 gals. to 50 sq. ft.	30	30-40	Normal, cold frame
Semesan (1924)	½ oz.; applied as dust	5.5	5-7	" " "
Semesan (1925)	½ oz.; applied as dust	Trace	5.2	Retarded growth on seed bed; improved transplated stand.

Since it has not been deemed essential, in view of the space requirements, to discuss in full the action of the various other compounds, a tabular record only is submitted (Tables VI and VII). In the garden plots Table VI, 100 sclerotia were placed at a depth of two inches, while in the potted sand, 200 to 300 sclerotia were mixed with the sand to a depth of four inches. From the garden plots following treatment, 25 sclerotia were taken and put into pots of sand so that conditions for germination might be better regulated. Viability was tested by apothecial production *in situ* in each case. Checks treated with formaldehyde as well as without were maintained. The results in Table VII were obtained upon larger plots, usually the area of five or more sash in coldframes or in the open field. The various items in this table represent experiments that were performed but once and thus the per cents of disease prevalence are records of single field readings rather than averages. As most of the results were decidedly negative, repetition of the experiments did not seem warranted.

Discussion of Results

A consideration of the occurrence of *Sclerotinia sclerotiorum*, *S. minor*, and *Botrytis sp.* in their varied phases of attack upon vegetables impresses one with the extreme difficulty or even impossibility of entirely eradicating them. Their ubiquity and the many ways of introduction and dissemination make the ideal of thorough eradication impracticable of attainment. It is evident, moreover, that there is no single means sufficient in itself for checking them. All the varied measures for control must be brought into play from time to time so that the inroads of disease may not make economical production impossible. Much may be accomplished by greater familiarity on the part of the practical grower with the habits of the parasites so that imminent trouble may be anticipated.

With respect to the control of disease in coldframes by the use of formaldehyde, the data presented appear to represent closely the average possibilities of this means of control in practice. Though the data do not give it high rank in efficiency as a measure of disease control, yet there are many instances when good returns for the outlay will be obtained. While a method is outlined for the elimination of much work in applying formaldehyde, labor should not be spared, especially in securing thorough distribution of the disinfectant through the soil.

SUMMARY

The fungi causing important loss to lettuce in Pennsylvania are *Sclerotinia sclerotiorum* (Lib.) Massee (*S. libertiana* Fckl.), *Botrytis sp.*, *Sclerotinia minor* Jagger, and *Rhizoctonia solani* Khun.

An average of the results of various experiments from 1919 to 1926 in treating lettuce seedbeds with formaldehyde shows a reduction in the prevalence of *Sclerotinia sclerotiorum* from 15.9 ± 1.4 per cent to 4.05 ± .6 per cent on lettuce maturing on the seedbed areas. In seedlings transplanted to the field, there was an increase from 74.4 ± .92 per cent stand without seedbed treatment to 88.5 ± .81 per cent with seedbed treatment. In this transplanted crop, the control was chiefly that of *Botrytis sp. and Rhizoctonia solani*. The treatments with formaldehyde paid a large return only when the soil was used primarily for the growth of lettuce seedlings.

Investigation of the killing action of formaldehyde upon the sclerotia of *Sclerotinia sclerotiorum* in garden soil at Bustleton showed highly variable results, efficient destruction of the sclerotia occurring only near the surface. The test of viability in this case was the recovery of the sclerotia from the treated soil and their germination on agar. In contrast, germination tests *in vitro* following treatments in potted sand showed high efficiency for formaldehyde. The contrast of results appears to be due to the better contact and distribution of the disinfectant in the sand and also to the fact that there is a greater disposition for partially destroyed sclerotia to decay in sand and soil. This disposition to decay is probably an important factor in the degree of control obtained in practice.

Treatments at Bustleton were less effective in killing the sclerotia in the deeper strata of soil than were the treatments reported by Krout (9) for the soil in Massachusetts lettuce greenhouses. The difference is caused apparently by the heavier

nature of the soil at Bustleton which prevents thorough distribution of the disinfectant.

Factors of importance favoring the efficiency of formaldehyde control of lettuce "drop" are a damp condition of the sclerotia prior to treatment, a loose or friable condition of the soil, and the working of the soil in the course of treatment to aid the even distribution of the disinfectant.

Experiments in which formaldehyde was spread upon the soil in very concentrated strength followed by the application of water did not show anything essentially or consistently opposed to such application in comparison with application in 1-100 strength. Application in great strength effected an important saving of labor.

The test of a considerable number of fungicides and chemicals besides formaldehyde for the control of "drop", herein reported, showed none that were efficient in reducing the disease and at the same time not injurious to the crop or not too expensive.

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